FHWA Geotechnical Research, Development, and Training (RD&T) Activities: A Summary Report

This report is intended to provide a brief but complete summary of all current and recently completed research, development and training activities by the Federal Highway Administration in the area of Geotechnical Engineering. Readers are encouraged to contact the identified key individual for additional information and assistance. The National FHWA Geotechnical Engineering RD&T activities can also be accessed at the FHWA Office of Bridge Technology's website www.fhwa.dot.gov/bridge.

RESEARCH ACTIVITIES

The Geogauge, SPR-2 (212)

Description: Many State DOT partners have joined the FHWA to evaluate the utility and effectiveness of a soil stiffness gauge developed for FHWA by the Humboldt Mfg. Company. This device, now called the GeoGauge, provides a simple, immediate and accurate way to directly measure in-place structural stiffness and in-place resilient modulus.

Use of the GeoGauge allows engineers to link design, specifications, construction and maintenance in a simple test that can be completed in a minute or two. The GeoGauge can also assist engineers in meeting compliance with modulus-based mechanistic design guidelines. During 2001, the number of state DOT's participating in this project rose to 26, with funding totaling over $0.6 million.

Each participating DOT received a GeoGauge, a standard work plan, and appropriate training to test and collect data for the evaluation program. In addition to the on-going field test studies, laboratory and data analysis studies were recently initiated to support the evaluation efforts. Most of the sponsoring DOTs participated in a workshop and planning meeting at FHWA's Turner-Fairbank Highway Research Center to develop a comprehensive work plan for conducting the evaluation studies. A technical working group was established to provide oversight and guidance for the study efforts.

A contract was awarded to Texas A&M University in August 2001 to perform an independent "Proof of Principle" review and a lab study to establish a target value for stiffness/modulus. The New Mexico DOT is also doing a lab study to establish appropriate target values. Field validation studies will begin shortly after target values are established. Current efforts also involve an evaluation of the data from the extensive fieldwork by Humboldt using a test strip procedure. A new seating procedure was developed to provide a standard for all users.

FHWA's Mike Adams conducted an in-house evaluation of the Humboldt calibration program to determine if the gauge could be easily calibrated by the owner, rather than sending it to the manufacturer. Calibration procedures were found to be too complicated and expensive for DOT use. FHWA then worked with Humboldt to develop a verification mass of lesser cost and verification masses were manufactured and shipped by FHWA to each participating DOT.

A "Pavement Variability Study" is also underway to evaluate the feasibility of using the GeoGauge to quantify pavement layer structural variability based on available GeoGauge stiffness data from current users. Preliminary indications show a high potential for determining variability with considerably reduced effort. Efforts are underway to develop an organized database to study the effects of layer thickness, material type and measurement techniques.

Discussions are also underway to develop a partnering arrangement with the EPA and Gas Technology Institute who are preparing to conduct an evaluation study of currently available devices for measuring compaction of soils. Several utility companies are co-sponsoring the work. The first phase of their study includes a comparative analysis of the GeoGauge and 5 other devices correlated with the nuclear density gauge. The devices will be ranked on the basis of test results and other factors such as ease of use and economics. The top two devices will be further evaluated in a field study to enhance the user-friendly capabilities of the chosen device.

Status: Arrangements have been made to conduct field tests during the 2003 construction season to evaluate the use of the Geogauge for assuring the quality of compaction via stiffness methods. In addition to Geogauge and moisture-density measurements, plate load tests and resilient modulus testing will be used to correlate the stiffness measurements to confirm empirically that a relationship exists between a conventional measure of percent compaction and stiffness.

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Deep Soil Mixing, TPF-5 (001)

Description: In May 2001, the FHWA initiated a pooled-fund study on deep mixing methods for solidifying groundmasses by blending in situ soils with cementicious materials. These methods have a wide spectrum of applications in the highway construction industry including soil retaining systems, mass stabilization, hydraulic barriers and liquefaction mitigation. Ten DOTs have pledged nearly $1 million to assist in the development of improved engineering guidelines for deep mixing methods.

Caltrans hosted a workshop in July 2001 to develop a prioritized list of research needs and perceived barriers to implementation and plans are underway to initiate additional research on this topic. Procurement plans are being developed to compile a knowledge database on in situ tests and their potential applications to perform accurate quality assessment of deep mixing methods in soils. Testing protocols will be developed for making reliable quality checks with each applicable tool. A synthesis report of findings will be the primary deliverable. A procurement action was initiated in March 2002 for the development of an evaluation report on current practices for making quality assessments of deep mixing methods in various parts of the world. The report will provide information on each of the various in-situ testing techniques and their capabilities to measure quality control and quality assurance aspects, including advantages, limitations with respect to soil types and cement mix levels, correlations with lab tests, typical testing time periods and cost details.

Other procurement actions underway include a study to develop a simplified method for selecting design dimensions for deep mixing treatment of seismic areas, the development of a deep mixing field inspection manual, a synthesis report on the state-of-the-practice for embankment stabilization, plus design charts for geosynthetically reinforced embankments on deep mixed columns. Arrangements were also made with the Swedish Geotechnical Institute to share the cost of translating three of their reports into English.

Status: Current efforts involve an engineering review of Swedish reports and several interim reports from on-going studies. Several new studies are being developed.

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Micropiles, TPF-5 (016)

Description: Eight DOT agencies have pooled $0.3 million to develop improved design and construction guidelines for the use of micropiles to support new and/or existing bridges to resist large forces, especially from extreme events such as earthquakes, ship impact, and scour. Initial efforts will concentrate on the development of a comprehensive database of case histories and guidelines for seismic retrofit and slope stabilization application, as well as other difficult engineering problems not adequately treated in existing design manuals.

A project "kickoff" meeting was held in November 2001, to develop a prioritized list of research needs and procurement plans. The meeting was scheduled in conjunction with an ADSC seminar on micropiles in Charlotte, NC to help the DOT participants become more familiar with pressing issues of this technology. Initial procurement plans are being developed. The first procurement action involved a contract with Geosystems, Inc. in October 2002 for the review and analysis of recent full-scale experiments conducted by the U.S. Military on reticulated micropile networks. In addition to cataloging all the soils

and load test data, the consultant will provide an interpretation of the load test results to illustrate the effect of configurations and loading directions.

Status: The results of the initial load test study will be used to provide guidance on the best pile configurations to model and test under a pending study to be initiated in May 2003. The objective of the new study is to analytically investigate and develop strategies for pile cap reinforcing using inclined micropiles in close proximity. The analytical results will be used to develop guidelines on pile configuration.

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Lateral Load Testing of Drilled Shafts, TPF-5 (032)

Description: Another pooled-fund study was initiated in June 2002 to support a comprehensive research project funded by the Arizona DOT and FHWA in conjunction with Arizona State University. The load/deformation behavior of single and groups of shafts in sandy gravel and cemented materials will be investigated. Several other DOTs have pledged support, and two sites have been selected for the load test program.

A sandy gravel site is located in a river bottom deposit with moderately clean coarse-grained soil with material ranging up to cobbles. The cemented soil site is located on the East side of the Phoenix valley in a predominantly fine-grained alluvial deposit.

At each of these sites, two groups of 6 shafts each will be constructed. All shafts will be 36 inches in diameter and 35 feet long. One of the groups will be loaded laterally only. To provide benchmark reference values to compare the group response to the single shaft response, a total of 6 single shafts will be loaded – four laterally and two axially. A total of 36 shafts will be tested at the two sites. This total includes 24 shafts in four groups of 6 shafts loaded laterally, and 12 shafts to be loaded individually and then used as reaction shafts. Eight of the single shafts will be loaded laterally and 4 axially. Six shafts in two, three-shaft groups will be loaded vertically.

Status: A contract was awarded in February 2003 to Arizona State University to obtain geotechnical data at various load test sites to validate a recently developed model for predicting the capacity of drilled shafts in gravels. A large database of load tests was developed but this lacks sufficient soils data. The model will be used to design the load tests described above and the results will in turn, be used to further refine the analytical model.

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Impulse Shear Test System, TPF-5 (031)

Description: Verification of a new FHWA device for obtaining geotechnical parameters for seismic design and analysis is also underway. A simplified torsional cylindrical impulse shear test system is used to characterize soft soil deposits to obtain in situ shear verses strain characteristics that are needed for dynamic earthquake analysis procedures. Being able to accurately provide information on the degradation, liquefaction potential, and large cyclic deformation characteristics of problem soils in seismic areas will be a significant breakthrough in geotechnical design.

The test program is aimed at verifying the reliability, efficiency, and applicability of the test system for assisting in the design of bridges to resist earthquake forces. Field tests will be conducted at the national seismic test site at Treasure Island in the San Francisco Bay area and at sites provided by participating state DOTs. Results will be used to design equipment enhancements to provide quick and easy use in a cost effective manner, especially to increase productivity and speed of operation. A work order was initiated in July 2002 to develop a work plan to assess all previous evaluation and verification activities for the device to determine the need to improve the accessory equipment assembly that is used to operate the probe, especially the problem of the existing assembly being difficult and time consuming to setup and breakdown.

Status: A second contract was awarded in February 2003 to provide assistance in maintaining and developing enhancements for the probe device. The contractor will design and build a replacement data acquisition and control system and develop a trailer-mounted probe bed. Routine maintenance and repair functions will also be conducted.

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Segmental Retaining Wall Blocks, SPF-2 (218)

Description: Another investigation sponsored by 12 DOTs involves the durability of segmental retaining wall (SRW) blocks. Studies are underway to develop specifications to ensure that quality blocks are used on highway projects.

This project involves the examination of the cause and effect of freeze/thaw conditions, as well as other environmental factors. Results will be used to develop corrective measures to preserve existing SRW blocks in harsh environments.

Several State DOTs are conducting investigations into the durability of concrete modular block wall systems to identify the extent of moderate to severe deterioration in their SRW blocks that have been in service for at least 5 years. Some of the northern tier states attribute some of the deterioration to freeze-thaw susceptibility of the dry cast blocks. Deicing salts are also considered to be a significant factor in accelerating the deterioration of SRW blocks. It is also apparent that some earlier walls were built with poor quality blocks due to a lack of adequate specifications.

A meeting of participating DOTs and FHWA representatives was held in May 2000 to discuss the performance issues of SRW blocks. Private sector representatives were also invited to discuss concerns with modular block fabrication. The participants developed a list of research topics that should be initiated to establish design and durability performance criteria, service evaluation and inspection guidance, and acceptance testing protocols.

Initial research efforts are concentrating on forensic investigations, performance testing, and specification development. Existing walls will be examined to detect and/or verify why some blocks are deteriorating. The dominant environmental factors influencing block durability will be determined as well as the influence of aggregate quality, cement content and type, and additives. New test procedures may need to be developed to accurately predict field performance. Performance based specifications will be developed to insure a 75 year design life for different climatic regions.

Status: A contract was signed in September 2002 with the University of Texas. A progress review meeting was held in March 2003 to discuss the research plan and bring together members of the contractor's research team with State DOT, FHWA, and industry representatives to agree on a comprehensive work plan.

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Automated Geotechnical Information and Design System (AGIDS), TPF-5(038)

Description: This pooled-fund study supports the FHWA's geotechnical information repository and design-aid system for practitioners and researchers to rapidly obtain high-quality geotechnical data for comparative analysis. The study involves the comprehensive integration of several geotechnical databases and computer modules that can be used to quickly and economically obtain information from a centrally located computer source for evaluation of design alternatives. The formal name of the program is "Automated Geotechnical Information and Design System" (AGIDS).

The integration effort involves the development of commonality features between the various elements, and the design of a user interface application for performing cross queries, correlations and engineering analysis. The AGIDS databases will be linked through a multi-user workstation that contains an interactive system for generating design solutions from the data repositories and engineering modules. The entire system will be web-enabled. The information to access the AGIDS databases can be found at: http://www.tfhrc.gov/structur/agids/agids.htm.

Several procurement actions were initiated in 2002. A small Purchase Order (P.O.) was issued to SYBASE, Inc. to provide database maintenance services for AGIDS. Another P.O. was prepared to install and Beta test an Internet Data Maintenance Application to

complete the Internet enabling of the soil related input forms. After installation and beta testing are complete, the contractor will begin data transfer operations from the old RISC 6000 server to the new SUN server. The contractor shall also train State DOT representatives and assign passwords and other security measures to maintain AGIDS integrity.

Another P.O. was issued to install Geo Media Web Maps on the FHWA server. The contractor, Intergraph Corporation will also provide consulting services and software to facilitate the development of the map-based interfaces to AGIDS. The contractor will focus the GIS-based application design and training tasks around geocoding latitude and longitude points associated with boring logs and load test locations.

Another P.O. was issued to develop a GIS based query interface for AGIDS. The contractor will work with the Intergraph personnel to perform necessary Windows web server setups and GIS software installation to integrate the Windows computer with the SYBASE server running on the Sun Unix OS.

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Geosynthetic Reinforced Pile Supported Embankments (GRPS), TPF-5 (061)

Description: A pooled fund study was initiated in September 2002 to develop design guidelines and to validate them against full-scale testing observations. GRPS embankments have been used before in embankment widening projects, retaining wall foundations, bridge approach fills, and for embankments on very soft soils overlying a stiff layer of bedrock. However, the available design methods are incomplete or unsatisfactory, requiring the development of a simple and efficient set of comprehensive design guidelines.

This study is a follow-up to a recently completed FHWA project to develop a comprehensive workplan for achieving the objective of developing the technical guidelines. A summary and assessment of current design methods was completed by Texas A&M University and a plan was developed to obtain the guidelines by performing numerical simulations to generate them and field-testing to verify them.

A 3-D finite element analysis program will be used to simulate the behavior of GRPS embankments. The soil and embankment fill will be simulated with a no-tension 3-D brick element, and the piles will be simulated with beam elements. The geosynthetic will be simulated with a no-compression membrane element. An elastic soil model will be used first, and then a non-linear soil model will be introduced.

The output will include the geosynthetic lineload, the pile axial load and bending moment, and the settlement at the top and bottom of the embankment. The many parameters that influence the calculation results will be varied. After all the runs are

performed, relationships between each design factor and all the influencing parameters will be derived. These relationships will form the design guidelines for the GRPS embankment.

Status: Arrangements are underway to initiate a contract research study to accomplish these objectives.

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Geosynthetic Reinforced Soil Structures

Description: Procedures for designing and constructing Geosynthetic Reinforced Soil (GRS) structures are being evaluated to develop improved techniques. Special emphasis is on using GRS technology to build bridge piers and abutments. Full-scale units and a series of large models have been constructed at TFHRC and other field locations to monitor performance during and after heavy load applications. Each of the full-scale structures were heavily instrumented to measure stresses and deformations in both the vertical and horizontal directions. Vertical spacing and connection strength issues are also being studied via analysis of the load test data.

Status: Load testing of the TFHRC abutments is nearly complete. Results from three comprehensive load tests are being analyzed and several more load tests are planned. Five large model piers were constructed and load tested at TFHRC, and four more at the Amherst NGES. Design and construction assistance was rendered in several States, including California, Colorado, Maryland, Tennessee, and Utah.

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Use of Composite Piles in Highway Bridge Foundations

Description: Based on a congressional mandate to study the use of composite piles, especially recycled plastic piles in bridge foundations, arrangements were made to conduct laboratory investigations at the United States Army Corps of Engineers Waterways Experiment Station (WES), plus two field studies in New York City and with the Virginia DOT. WES is studying the chemical durability, freeze/thaw, axial creep, and flexural rigidity aspects of these piles. New York is conducting a comprehensive field load-testing program and Virginia DOT is conducting long and short-term monitoring studies of an in-service composite pile group.

Status: The cooperative agreement with the WES is completed. The contract produced a Composite Pile Project Database, which documents the state of the practice up to the time

of the report. Analysis of the data collected indicates that two types of composite piles show potential promise for load-bearing applications pertinent to highway structures. These pile types are recycled plastic piles reinforced with fiberglass or steel rods and FRP shells filled with concrete with or without reinforcing steel. Chemical durability studies done to look at resistance to the high-pH condition that exists in hydrated Portland cement paste and to the high NaCl condition that piles would likely see in a marine environment verified that the filament wound FRP shells are insensitive to these environmental factors. Composite piles appear to be durable to freezing and thawing.

All laboratory and field work under the VTRC/VT contract has been completed and a draft report prepared. Three pile types were initially selected for office review, Lancaster Composite which manufactures its shells by the filament wound process, Hardcore Composite which are manufactured by vacuum assisted infusion molding of hand laid up fiber glass sheets, and Seaward Seapile manufactured from recycled HPDE plastic matrix reinforced with fiber glass rods. The Lancaster Composite FRP shell is filled with an expansive concrete and relies on the properties of the FRP shell to provide tensile resistance although steel reinforcing can be included. The Hardcore composite shell can be filled with concrete or the shell can be driven then filled. In either case, conventional non-expansive concrete is used with steel reinforcing and the shell is considered a stay-in-place form (provides environmental protection only). Only the FRP concrete filled shell piles were found potentially viable for medium to highly loaded bearing piles and were selected for field studies. Subsequently Lancaster composite chose not to have its pile evaluated and a new type of composite pile consisting of a welded steel cage encapsulated in a plastic matrix was substituted for field-testing. Field tests included dynamic monitoring and analysis, axial load tests, lateral load tests and installation and monitoring of concrete and FRP service piles.

Laboratory studies included an evaluation of the effects of water absorption, chemical attack and freeze-thaw on the strength and stiffness of FRP shells. These durability studies were for duration of approximately two years. Interface shear tests were done on materials from all three-pile types and on steel and concrete coupons for control.

The significant results from the laboratory and field tests are as follows:

- FRP shells made by the filament wound or vacuum assisted infusion molding were insensitive to chemical and freeze –thaw but did show degradation with time of stiffness and tensile strength of up to 24% due to water absorption. Further studies would be needed to assess the significance of these findings on service pile performance.
- Interface shear tests using two types of sands indicate a wide scatter within a range of 27.6 to 33 degrees for peak and 24.9 to 27.8 degrees for residual conditions for the Hardcore, PPI and steel and concrete control specimens. The Lancaster specimens yielded the lowest interface friction values at 19.7 and 16.6 degrees for peak and residual conditions respectively. Note that the friction resistance of Lancaster piles can be significantly increased with the bonding of fiberglass bands circumferentially around the pile.

- The axial stiffness (EA) of the FRP and concrete pile were similar to each other and about $2^1/_2$ times the axial stiffness of the plastic pile.
- The FRP and plastic pile were able to be evaluated using present dynamic procedures and equipment but the plastic pile did cause some initial problems because of the proximity of the steel to the surface and probable presence of voids.
- All three piles exhibited substantial set-up on restrike 5 days after installation.
- Axial capacity according to Davison's criterion gave 3090, 2260 and 2130 kN for the concrete, FRP and plastic pile respectively. All three piles exceed twice the design load criteria of 890 kN but as indicated above the plastic pile had approximately 22 mm of settlement compared to 12 mm for the concrete and FRP pile.
- All three piles exhibited similar load transfer behavior with on average about 70% of the load carried in skin friction and 30 in end bearing.
- The prestressed concrete pile and the FRP pile exhibited similar load-deflection response in static lateral load tests. The plastic pile exhibited much larger deflections at the same lateral loads.

Field-testing at the New York City site is completed. Data interpretation and analysis in initial stages, however, results of study will only be applicable to lightly loaded structures (40 tons or less design loads). Initial interpretation of the load test results yielded Davison failure loads of approximately 120, 85 and 85 tons respectively for the Lancaster, Plastic cage and Seaward pile piles. Relative deflections at these loads were 7 and 1.4 times the deflections of the Lancaster pile respectively for the Seaward and Plastic pile.

A draft speciation on the use of polymeric piles in axial and lateral load bearing applications, including but not limited to marine, waterfront and other highly corrosive environments is being prepared for submittal to ASTM Committee D-20 on Plastics. For details of contents of draft spec contact Keith Lashway, Empire State Development Corp (518) 292-5340, email: klashway@empire.state.ny.us.

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NCHRP 24-11: Guidelines for Geofoam Applications in Embankment Projects

Description: The use of geofoam in embankment construction avoids the problem of excessive settlements and affords benefits including reduction of overburden pressure, reduction in the magnitude of ultimate settlement, and savings in construction time. Differential settlements between the approach fill and bridge abutments can be reduced. Lateral pressure from approach fills onto abutments and wing walls can be lessened significantly with geofoam fill. Long-term maintenance requirements can be minimized,

and ride quality of roads crossing swamps or bog areas can also be improved by geofoam use.

These applications call for the detailed analysis of the behavior of the geofoam under stresses that will develop during long-term use. Such analyses require knowledge of the material properties of the geofoam under service loads as well as models to predict geofoam behavior and embankment performance.

The key issue for this research is the development of tools to predict the behavior of the geofoam under service loads and the long-term performance of the embankment. The objective of this research is to develop guidelines, including new test methods, design and analysis procedures, and construction specifications, for the use of geofoam as a super-lightweight fill in embankments and bridge approaches over soft ground.

Status: See the web link located directly below.
http://www4.trb.org/trb/crp.nsf/e7bcd526f5af4a2c8525672f006245fa/22bee51581b5573a8525674800561ab9?OpenDocument

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NCHRP: http://www4.trb.org/trb/crp.nsf/reference/appendices/NCHRP+Overview

NCHRP 24-21: LRFD Soil-Nailing Design and Construction Specifications

Description: The soil-nailing method of earth retention is the preferred retaining wall option for many cut applications. Advantages of soil-nailed retaining structures include cost, speed of construction, construction flexibility, and aesthetics. Federal Highway Administration (FHWA) Demonstration Project No. 103 developed a comprehensive design and construction manual (FHWA Report SA-96-069R; see Special Note C) for temporary and permanent soil-nailed structures. The FHWA soil-nailing manual contains a detailed design protocol for allowable stress design (ASD) and an early, but incomplete, Load and Resistance Factor Design (LRFD) approach.

The *AASHTO Standard Bridge Specifications*, the *AASHTO LRFD Bridge Design Specifications* and the *AASHTO LRFD Bridge Construction Specifications* do not provide guidance on design and construction of soil-nailed structures. With the absence of AASHTO specifications, some state DOTs are not yet using soil nailed retaining structures. Given the advantages of soil-nailed structures, there is a need to develop standard design and construction specifications for soil-nailed structures for incorporation into the AASHTO LRFD Bridge Design and Construction Specifications.

The objective of this research is to develop recommended LRFD design specifications and LRFD construction specifications for soil-nailed retaining structures.

Status: See the web link located directly below.
http://www4.trb.org/trb/crp.nsf/e7bcd526f5af4a2c8525672f006245fa/aa2c923304f8e87b85256b9900452956?OpenDocument

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NCHRP 24-22: Selecting Backfill Materials for MSE Retaining Walls

Description: Existing AASHTO specifications for construction of mechanically stabilized earth (MSE) retaining walls require the use of high-quality, free-draining, granular backfill. In many areas, the availability of high-quality structural backfill has been decreasing. It is anticipated that as backfill supplies decrease costs will most likely increase. Research and practice indicates that many soils other than those classified as AASHTO A-1-a soils have high strength (friction angles higher than 34 degrees) and have been shown to be suitable as backfill within the reinforced zone of MSE retaining walls.

The objective of this research is to develop selection guidelines, soil parameters, testing methods, and construction specifications that will allow the use of a wider range of backfill materials within the reinforced zone of mechanically stabilized earth (MSE) retaining walls.

Status: See the web link located directly below.
http://www4.trb.org/trb/crp.nsf/e7bcd526f5af4a2c8525672f006245fa/bcf29e9145670afe85256b9900452ff8?OpenDocument

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NCHRP 12-59: Design and Construction of Segmental Geosynthetic Reinforced Soil (GRS) Bridge Abutments for Bridge Support

Description: GRS bridge abutments and piers are more forgiving to differential foundation settlement, more adaptable to low-quality backfill, easier to construct, and more economical than their conventional counterparts. GRS bridge abutments and piers can be put into service quickly and can be built by maintenance personnel. This system may have considerable advantages for pedestrian structures, especially where access by heavy equipment is not available. It is economical for (a) temporary pier use because of its easy demolition and the recyclable nature of its components; (b) emergency work because of reduced lead time and lower equipment needs and skills; and (c) massive-looking piers that are desired for aesthetic reasons.

Full-scale tests conducted by the FHWA and by the Colorado Department of

Transportation (DOT) in Denver on GRS bridge abutments and piers with segmental modular block facing have demonstrated excellent performance characteristics and very high load-carrying capacity. In these tests, the bridge was supported directly on the GRS mass.

The objective of this project is to develop rational, reliable design and construction guidelines for geosynthetic-reinforced soil (GRS) bridge abutments and approaches with flexible facing elements.

Status: See the web link located directly below.
http://www4.trb.org/trb/crp.nsf/e7bcd526f5af4a2c8525672f006245fa/a3b50a1b5bbcd87a852568c4006db028?OpenDocument

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NCHRP 12-55: Load and Resistance Factor Design (LRFD) Specifications for Bridge Substructures

Description: The AASHTO LRFD Bridge Design Specifications were developed to implement a more rational approach for the design of highway structures. As opposed to allowable stress design (ASD), wherein all uncertainty is embedded within a factor of safety, the LRFD approach applies separate factors to account for uncertainty in load and material resistance. The load and resistance factors developed for the LRFD specifications were calibrated using a combination of reliability theory, fitting to ASD, and engineering judgment. Calibration using reliability theory is preferred because the approach permits selection of a target reliability or safety index that reflects the probability of failure of a structural component. However, reliability-based calibration requires access to sufficient data to statistically define the variation and distribution of load and resistance using mathematical relationships. Calibration by fitting and judgment was used in conjunction with reliability-based calibration, or in lieu of reliability-based calibration when sufficient data were not available, to ensure that designs were comparable with accepted engineering practice.

The load factors for soil loads were developed by correlating to ASD designs and engineering judgment. Reliability-based soil load and resistance factors based on available data are needed. In addition, no framework exists for adjusting soil load factors based on the quantity and quality of site data.

The objective of the research is to develop recommended load and resistance factors for foundations and retaining walls for possible inclusion in the AASHTO LRFD Bridge Design Specifications. Lateral, vertical, and surcharge earth loads are to be investigated.

Status: See the web link located directly below.

http://www4.trb.org/trb/crp.nsf/e7bcd526f5af4a2c8525672f006245fa/020cd52229d04560852568c4006c483e?OpenDocument

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Boston CA/T Load Test Summary Reports

Description: A large number of static and dynamic pile load tests have been performed on numerous contracts for the Boston Central Artery Project (Big Dig). As a result a wealth of cost data and load test information has been collected over the project history and many lessons learned through the construction stage. Proposed is a summary document that will include the results of the static and dynamic load tests project wide, a driven pile cost data summary, constructability issues at various sites and an overview of the project design criteria and project specifications.

Status: Work began January 1, 2003.

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DEVELOPMENT ACTIVITIES

National Geotechnical Inspector Certification Program

Description: To improve the quality of our constructed highway facilities a certification program for geotechnical field inspection and site investigation activities is being developed. The program will be targeted at those personnel involved in construction inspection, site investigation and field and laboratory testing. The ultimate goal of the program is the development of a nationally accepted certification program that will serve to improve quality, ensure uniformity and establish a minimum standard of construction control for geotechnical work. Inspector Certification Modules to be developed include: Deep Foundations (Driven Piles and Drilled Shaft Foundations); Soils Boring Inspector; Earth Retaining Walls; Embankments/Cut Slopes/Reinforced Soils Slopes (RSS); Anchored/Soil-Nail Walls.

Status: TWG has been formed, Strategic Plan developed. Driven Pile and Drilled Shaft Modules have been completed. Subsurface Technician and MSEW/RSS Modules are under development.

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FHWA Innovations and Advancements Program: Boston Central Artery Summary Reports

Description: The Central Artery/Tunnel (CA/T) Project in Boston is the largest and most challenging underground highway construction project in the heart of a major US city. With its popular name "BIG DIG", the CA/T Project incorporated many geotechnical innovations. As a result, a wealth of design, performance, and cost data have been collected over the project history and many lessons learned through the construction stage.
Proposed are three summary documents:
1. Geotechnical Instrumentation – Lessons Learned on the CA/T Project
2. Soil/Cement Mix Methods – Lessons Learned on the CA/T Project
3. Support of Excavation Systems – Lessons Learned on the CA/T Project.

Status: Instrumentation Report under development; RFP's for Deep Mixing and Support of Excavations Reports out, contract awarded March 2003. Time to complete reports is estimated at 18 to 24 months.

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Geotechnical Engineering Circulars (GEC)

Description: A series of geotechnical engineering manuals very similar to the successful Hydraulic Engineering Circulars (HEC's) are being written. The objective is to provide FHWA's recommended design and construction monitoring practices in a maturely developed technology.

Status: GEC's 1-6 have been distributed:

1. Dynamic Compaction (SA-95-037)
2. Earth Retaining Structures (SA-96-038)
3. Earthquake Engineering for Highways Volumes I and II (SA-97-076/77)
4. Ground Anchors and Anchored Systems (IF-99-015)
5. Evaluation of Soil and Rock Properties (IF-02-034)
6. Shallow Foundations (IF-02-054)

GEC's 1, 3, 4, 5 and 6 are available electronically from the Bridge web site. GEC 7, Soil Nailing, has been completed and will be distributed in April 2003.

Topics for future GEC's include soil mixing, geophysics/remote sensing, soil slopes and embankments, deep foundations, ground improvement techniques and rock slopes.

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World Road Association - PIARC
http://www.piarc.inrets.fr/index-e.htm

Committee N° 12 - Earthworks, Drainage, Subgrades
http://www.piarc.inrets.fr/cgq/c12-gene.htm

Description: PIARC (the World Road Association) Technical Committees are tasked with producing reports on best practices and recommendations in their respective fields thereby assisting decision makers, road engineers, and research engineers. They play an active role in the preparation of the World Road Congresses.

Technical Committees consist of distinguished engineers and experts appointed by member countries. They meet on average twice a year between Congresses allowing them to discuss and report on their work program.

During the 2000-2003 inter-Congress period more than 850 engineers and experts from over 50 member countries and International Agencies are participating in Committee meetings. PIARC Technical Committees provide an excellent international personal contact network. PIARC is actively seeking to involve more participants from developing and transitional countries in the work of its Technical Committees.

Status: The FHWA is an active member within technical committees of PIARC, including the geotechnical committee C12 for which it has had an active member over the last 10-years. Current products and publications under development by C12 include:

- Natural Materials Not Compliant With Specification and Relevance of Earthworks Control
- Performance of Ground Improvement Techniques for Embankment Foundations
- Strategic Framework for Managing Geotechnical Risk

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2002 Joint AASHTO/FHWA Scanning Trip
Innovative Technology for Accelerated Construction of Bridge and Embankment Foundations

Description: Development and implementation of accelerated construction and rehabilitation technology is imperative to the long-term health of the U.S. infrastructure system and economy. Recognition of accelerated construction as a national imperative is underscored by the recent Transportation Research Board, Task Force A5T60 Workshop "Accelerating Opportunities for Innovation in the Highway Industry."

The pace of this process can be significantly increased and costs reduced by drawing upon European technology and expertise in this area. Europe's procurement process and population density have driven forward and necessitated rapid innovation in accelerated construction. For example, the leading foundation contractors in Europe all develop and build their own equipment to suit their specific needs and proprietary foundation systems. In addition to speed of construction requirements, their technology addresses many other issues that are coming to the forefront of US Highway construction--limited space, noise limitations, vibration control, pollution, etc.

The objectives of the Scanning Trip were:

1. Discover and Evaluate European Technology for Accelerated Construction and Rehabilitation of Bridge and Embankment Foundations.
2. Identify and recommend successful European Technology for Accelerated Construction and Rehabilitation for immediate application in the U.S.
3. Facilitate leveraging of U.S. resources with those in Europe for cooperative research, development, and implementation of accelerated construction technology.

The Scope of the Scanning Trip was as follows:

1. Evaluate the applicability of Technology currently being used in Europe for accelerated construction. This would be accomplished via:
   a) Physical demonstrations of the technology
   b) Interviews
   c) Case Study Briefings

   The technologies to be evaluated included:
   i. New bridge and embankment foundation systems.
   ii. Foundation equipment and technology for accelerated construction and rehabilitation.
   iii. Innovative Earth Retention Systems for accelerated construction and rehabilitation.
   iv. Innovative technology for accelerated ground improvement of bridge and embankment foundations.

2. Identify and evaluate completed and on going European Research in areas i-iv as identified above. The objectives are:
   a) Collect useful information for dissemination in the US.
   b) Identify and facilitate future research partnerships as was successfully accomplished by the '93 Soil Nailing Scanning Trip in '93.
   c) Eliminate redundant efforts in the U.S.

3. Establish R&D priorities in the US for Accelerated Foundation and Construction and Rehabilitation.

Status: Project was approved by FHWA (HQ & RC Managers) and AASHTO in March of 2001. The Scanning Trip was completed in June of 2002. In January 2003, TRB held Workshop 116: Innovative Technology for Accelerated Construction of Bridge and Embankment Foundations. The DRAFT final scanning trip report is available at the following web link: http://www.fhwa.dot.gov/bridge/bescan.htm.

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TRAINING ACTIVITIES

- Additional information on the NHI courses, including course schedules, is available from the NHI web site at http://www.nhi.fhwa.dot.gov
- The course catalog for Geotechnical Engineering is available from the following: http://www.nhi.fhwa.dot.gov/category.asp?category_id=4
- **FHWA instructors are needed to assist in the updating and to deliver the courses.** Contact Larry Jones, NHI Training Program Manager, at NHI for more information (703) 235-0523.
- FHWA Geotechnical Publications may be accessed at the following web link: http://www.fhwa.dot.gov/bridge/geopub.htm

Geotechnical and Foundation Engineering - NHI Course No. 132016

Description: This advanced course, currently under development, will address all aspects of Geotechnical and Foundation Engineering. The course is divided into eleven stand-alone modules. A state-of-the-art manual for each module will be provided as a practical reference for later use.
Status: Under development; 8 of eleven modules completed to date.
Contacts: Jerry DiMaggio, Senior Geotechnical Engineer, FHWA HQ's
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Module 1: Subsurface Investigation – NHI Course No. 132031

Description: 3-day course covering the latest methods and procedures in the planning, execution and interpretation of the various subsurface investigation methods and the development of appropriate soil and rock design parameters for engineering applications.
Status: Courses are currently being offered through NHI.
Contact: Peter W. Osborn, Operations/Geotechnical Engineer, RI Division
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Module 2: Geotechnical Contracting and Quality Assurance/Quality Control – NHI Course No. 132032

Description: Module 2 is offered as a separate half-day course covering technical and administrative aspects associated with the contracting and quality assurance/quality control of geotechnical design and construction monitoring.
Status: Development of this course has been deferred based on budgeting issues.

Module 3: Soil Slope and Embankment Design – NHI Course No. 132033

Description: Module 3 of the 4-week course is also offered as a separate two and one-half day course covering important aspects associated with the design and construction of soil slopes and embankments including landslide analysis and repair.
Status: Courses are currently being offered through NHI.
Contacts: Sam Mansukhani, Geotechnical Engineer, MRC
(708) 283-3550, sam.mansukhani@fhwa.dot.gov
Jerry DiMaggio, Senior Geotechnical Engineer, FHWA HQ's
(202) 366-1569, jerry.dimaggio@fhwa.dot.gov

Module 4: Ground Improvement Techniques – NHI Course No. 132034

Description: Module 4 of the 4-week course will be offered as a separate three-day course covering important design and construction aspects associated with ground improvement techniques. Topics on ground improvement techniques include: grouting, vertical drains, stone columns, lightweight fill, vibro-compaction, dynamic compaction, deep soil mixing and other new and innovative ground improvement concepts.
Status: This course will be developed as an updated version of Demonstration Project 116. The updated course is on schedule to be offered in the spring of 2004.
Contact: Jerry DiMaggio, Senior Geotechnical Engineer, FHWA HQ's
(202) 366-1569, jerry.dimaggio@fhwa.dot.gov

Module 5: Rock Slopes – NHI Course No. 132035

Description: Module 5 is an individual stand alone two day short course covering the design and construction aspects associated with rock slopes. The course presents

appropriate geological investigation techniques, shear strength theories and determination of rock strength, and various design methods for rock slopes with different failure mechanisms. Other topics include: rock blasting, rock slope stabilization methods and contracting issues. Classroom instructions include the discussion of sample problems and case histories involving rock slope analyses and design.
Status: Courses are currently being offered through NHI.
Contact: Barry Siel, Geotechnical Engineer, WRC
(303) 716-2191, **barry.siel@fhwa.dot.gov**

Module 6: Earth Retaining Structures – NHI Course No. 132036

Description: A separate three-day course covering the selection, design, construction and performance of earth retaining structures used for support of fills or excavations. Factors that affect wall selection are discussed, including contracting approaches with an emphasis on required bidding documents for each approach. Class discussions will include design procedures and case histories, demonstrating the selection, design and performance of various earth retaining structures.
Status: Courses are currently being offered through NHI.
Contact: Barry Siel, Geotechnical Engineer, WRC
(303) 716-2191, **barry.siel@fhwa.dot.gov**

Module 7: Shallow Foundations – NHI Course No. 132037

Description: Module 7 of the 4-week course is also offered as a separate 2-½ day course covering the design and construction of shallow foundations on both natural ground and engineered fills.
Status: Courses are currently being offered through NHI.
Contact: Jerry DiMaggio, Senior Geotechnical Engineer, FHWA HQ's
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Module 8: Deep Foundations – NHI Course No. 132038

Description: Module 8 of the 4-week course is offered as a separate three-day course covering the design and construction of deep foundations.
Status: Development of this module has been deferred based on budget limitations. See NHI courses on drilled shafts and driven piles.

Module 9: Geotechnical Earthquake Engineering – NHI Course No. 132039

Description: An advanced 2 ½ -day course covering seismic design issues associated with geotechnical engineering.

Status: To be updated with new AASHTO Seismic Specifications and MCEER Retrofit Manuals (FY 04 – 05); Updated Course complete by FY06.
Contact: Peter W. Osborn, Operations/Geotechnical Engineer, RI Division
(401) 528-4550, peter.Osborn@fhwa.dot.gov

Module 10: Geotechnical Aspects of Pavements – NHI Course No. 132040

Description: Module 10 of the 4-week course is offered as a separate 2-day course covering the geotechnical issues associated with pavement design.
Status: Development began in November 2002. Expected completion date is October 2003.
Contacts: Sam Mansukhani, Geotechnical Engineer, MRC
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Module 11: Geotechnical Instrumentation – NHI Course No. 132041

Description: The course is designed to provide the student with the necessary knowledge and skills to plan, select, and implement instrumentation programs in geotechnical features for construction monitoring and performance verification.
Status: Courses are currently being offered through NHI.
Contact: Peter W. Osborn, Operations/Geotechnical Engineer, RI Division
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Soils and Foundations Workshop – NHI Course No. 132012

Description: A 4-day workshop geared to the practicing engineer who routinely deals with soils and foundations problems, but has little theoretical background.
Status: Courses are currently being offered through NHI.
Contacts: Silas Nichols, Geotechnical Engineer, ERC
(410) 962-2460, silas.Nichols@fhwa.dot.gov
Jerry DiMaggio, Senior Geotechnical Engineer, FHWA HQ's
(202) 366-1569, **jerry.dimaggio@fhwa.dot.gov**

Design of MSE Walls and Reinforced Soil Slopes – NHI Course No. 132042

Description: Conversion of Demonstration Project 82 into a NHI training course. The purpose of this three-day course is to optimize the implementation of mechanically stabilized earth technology in routine transportation design and construction practice.
Status: Courses are currently being offered through NHI.
Contact: Jerry DiMaggio, Senior Geotechnical Engineer, FHWA HQ's
(202) 366-1569, **jerry.dimaggio@fhwa.dot.gov**

Geosynthetics Engineering Workshop – NHI Course No. 132013

Description: The 1-day Summary course provides an introduction to geosynthetics, focusing on identifying, specifying, testing, installing, and inspecting geosynthetic installations.
Status: Courses are currently being offered through NHI.
Contact: Jerry DiMaggio, Senior Geotechnical Engineer, FHWA HQ's
(202) 366-1569, **jerry.dimaggio@fhwa.dot.gov**

Construction Inspection of MSE Walls and Reinforced Soil Slopes – NHI Course No. 132043

Description: Conversion of Demonstration Project 82 into a one-day NHI training course that focuses on proper construction quality control and assurance procedures for mechanically stabilized earth walls and reinforced soil slopes.
Status: The updated version of the technical manuals and training materials has been completed and requests for presentation are currently being accepted.
Contact: Jerry DiMaggio, Senior Geotechnical Engineer, FHWA HQ's
(202) 366-1569, **jerry.dimaggio@fhwa.dot.gov**

Drilled Shafts: Construction Procedures and Design Methods – NHI Course No. 132014

Description: This 3-day course is designed to give participants knowledge of the entire process of designing, installing, monitoring, and maintaining drilled shafts.
Status: This course has had an extensive revision based on FHWA's new Drilled Shaft Manual FHWA-IF-99-025. Courses are currently being scheduled through NHI.
Contact: Jerry DiMaggio, Senior Geotechnical Engineer, FHWA HQ's
(202) 366-1569, **jerry.dimaggio@fhwa.dot.gov**

Driven Pile Foundations: Design and Construction – NHI Course No. 132021

Description: This course covers the practical application of pile technology and addresses current methods of driven pile technology, with the emphasis on data interpretation and decision making issues common to real life construction projects. This course on basic design and construction covers all aspects of driven pile technology.
Status: Currently available. Minor updates to be made in 2003.
Contact: Peter W. Osborn, Operations/Geotechnical Engineer, RI Division
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Driven Pile Foundations: Construction Monitoring – NHI Course No. 132022

Description: This course provides information on current methods of driven pile technology with emphasis on data interpretation and decision-making issues common to driven pile installation and monitoring during construction.
Status: Currently available. Minor updates to be made in 2003.
Contact: Peter W. Osborn, Operations/Geotechnical Engineer, RI Division
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Load and Resistance Factor Design (LRFD) for Highway Bridge Substructures – NHI Course No. 132068

Description: This two-day course was developed to provide current technical aspects on the design of highway bridge substructures using the Load and Resistance Factor Design (LRFD) method. Over 60 training sessions have been completed in the past.
Status: This course is temporarily unavailable. The new AASHTO LRFD Bridge Design Specifications are being updated. This course is expected for delivery in 2005.
Contact: Jerry DiMaggio, Senior Geotechnical Engineer, FHWA HQ's
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Driven Pile Foundation Inspection – NHI No. 132069

Description: This course was developed to provide a basis for local, regional or national qualification for pile driving inspectors of all States. The goal of this course is to provide pile driving inspectors with the practical knowledge and accepted standard industry practices for the inspection of pile driving construction operations. This course is designed for foundation inspectors, who are responsible for or involved in pile driving operations during construction. Presentation of the course is in an interactive format so that the participants are actively involved in the learning experience. A two-hour qualification exam is administered on the third day of the course.
Status: Available after January 1st, 2003.
Contact: Peter W. Osborn, Operations/Geotechnical Engineer, RI Division
(401) 528-4550, peter.Osborn@fhwa.dot.gov

Drilled Shaft Foundation Inspection – NHI No. 132070

Description: The Drilled Shaft Foundation Inspection course is a stand-alone training course developed to provide a basis for local, regional, or national qualification of drilled shaft foundation inspectors. The goal of this course is to provide drilled shaft foundation inspectors with practical knowledge and standard industry practices for the inspection of drilled shaft foundation construction. This course is designed to be of most benefit to foundation inspectors, who are responsible for or involved in providing inspection of drilled shafts during construction. Presentation of the course is in an interactive format so that the participants are actively involved in the learning experience. A two-hour qualification exam is administered on the third day of the course.

Status: Available after January 1st, 2003.
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